U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
WISCONSIN DEPARTMENT OF NATURAL RESOURCES

HYDROLOGIC INVESTIGATIONS ATLAS HA-731
Hydrogeologic sections, ground-water province II—SHEET 3 OF 4
Kammerer, P.A., and others, 1998, Geology, ground-water flow, and dissolved-solids concentrations in ground water along hydrogeologic sections through Wisconsin aquifers

GROUND-WATER PROVINCE II

GEOLOGY

PRECAMBRIAN ROCKS

Precambrian rocks that underlie province II are crystalline rocks of the basement complex. The Precambrian surface is covered by Paleozoic sedimentary rocks except in the northwest along the boundary between provinces II and III where Precambrian rocks are the uppermost bedrock. Precambrian rocks are near the land surface and have as much as 600 feet of relief in the Fond du Lac Range (section D'–D') (Thwaites, 1931). The general dip of the Precambrian rocks is to the east in the northern two-thirds of the province and to the southeast in the southern one-third (Thwaites, 1957). The surface of the Precambrian rocks is more than 2,500 feet below sea level in the southeastern corner of the province.

Several major faults have been described. Section E'–E' intersects a fault southwest of Green Bay. Several faults are in the Waukesha area (section B'–B'). P.R. Wright (University of Wisconsin, unpub. B.A. thesis, 1930) and Thwaites (1931, p. 736) describe a fault that extends to the west from Waukesha to east of Dodgeville (Iowa County). A fault that extends northwest from Waukesha is shown by Mudrey and others (1982). At Waukesha, this fault intersects one that extends northeast and southwest from Waukesha (Thwaites, 1957; King, 1969; Dutton and Bradley, 1970; Mudrey and others, 1982; P.R. Wright (University of Wisconsin, unpub. data, 1930).

PALEOZOIC ROCKS

The Paleozoic sedimentary rocks that overlie the Precambrian rocks within most of the province include the Mount Simon, the Eau Claire, and the Wonewoc Sandstones; the Tunnel City Group; the St. Lawrence Formation; the Jordan Sandstone; the Prairie du Chien, the Ancell, and the Sinnipee Groups; the Maquoketa and the Neda Formations; Silurian rocks; and Devonian rocks.

The Mount Simon Sandstone thickens greatly to the southeast where the Precambrian surface is very deep. Because of its great thickness and the adequacy of aquifers nearer the surface, it generally is not fully penetrated by wells. Logs of deep wells at Burlington (section C'–C'), Mayville (section E'–E'), Sheboygan, Jacksonport, and Milwaukee (section F–F') indicate that the Mount Simon Sandstone contains thin shale layers similar to those found in the upper part of the Eau Claire Sandstone. Nevertheless, the Mount Simon Sandstone is a highly productive aquifer within most of the province. It is medium- to coarse-grained sandstone that is poorly cemented by dolomite in most places and by silica locally (M.E. Ostrom, Wisconsin Geological and Natural History Survey, written commun., 1982). The Mount Simon Sandstone is greater than 600 feet thick in the southeast; it is about 1,780 feet thick at Zion, Illinois (section F–F').

The Eau Claire Sandstone generally can be divided into a lower sandy unit and an upper shaly unit where its thickness exceeds 100 feet. In most of province II, only the lower unit remains because the upper unit was removed by pre-Wonewoc erosion. The lower unit is a fine- to medium-grained dolomitic sandstone with some shale beds; it is poorly cemented by dolomite in most places and well cemented by dolomite locally. The Eau Claire Sandstone yields only moderate quantities of water to wells, and the shale beds from Dodge County southwards are confining units between the overlying and underlying sandstones.

The Wonewoc Sandstone varies considerably in thickness areally because it was deposited on an irregular erosion surface. The sandstone generally is medium- to coarse-grained and poorly cemented by dolomite in most places and by silica locally (M.E. Ostrom, Wisconsin Geological and Natural History Survey, written commun., 1982). It yields large quantities of water to wells in many areas.

The rocks of the Elk Mound Group (the Mount Simon, the Eau Claire, and the Wonewoc Sandstones) are undivided in hydrogeologic sections north of Fond du Lac (section E'–E') and north of an area about midway between Milwaukee and Cedarburg (section F–F') because no clear formation breaks can be identified in well cuttings.

The Tunnel City Group is a well-cemented dolomitic sandstone that consists of two facies distinguished by the presence or absence of the mineral glauconite (Odom, 1978). The glauconitic facies is a fine- to medium-grained, but locally fine-grained, feldspathic sandstone. The glauconitic facies apparently is the only facies present in the southern two-thirds of the province. The nonglauconitic facies is a fine- to medium-grained feldspathic sandstone or, locally, a sandy dolomite. The sandy dolomite is common near Jacksonport (section F–F') and Cave Point (section K'–K'). The Tunnel City Group is moderately to well cemented by dolomite (M.E. Ostrom, Wisconsin Geological and Natural History Survey, written commun., 1982). The thickness of the Tunnel City Group gradually increases to the north from about 50 feet at Racine (section F–F') to about 100 feet at Green Bay (section E'–E'). The Tunnel City Group yields moderate quantities of water to wells.

The St. Lawrence Formation consists of interfingering facies of the dolomite and sandy dolomite of the Black Earth Member and the dolomite-cemented siltstone and very fine-grained shaly sandstone of the Lodi Shale Member (M.E. Ostrom, Wisconsin Geological and Natural History Survey, written commun., 1982). The Lodi Shale Member is as much as 30 feet thick between Mayville and Fond du Lac (section E'–E'), but the Black Earth Member constitutes most of the thickness of the St. Lawrence Formation in the rest of province II. The total thickness of the St. Lawrence Formation differs areally because pre-Jordan erosion removed the upper part of the St. Lawrence in the west. Erosion before deposition of the Ancell Group completely removed the St. Lawrence Formation in an area east of a line from Manitowoc (section F–F') to Fond du Lac (section D'–D') to Wales (section B'–B') to Cudahy (section F–F'). The St. Lawrence Formation is a confining unit and an unproductive source of water.

The Jordan Sandstone is a very fine-grained to medium-grained white to orange sandstone. It is poorly to well cemented by dolomite, calcite, or silica. The maximum thickness of the Jordan Sandstone (about 60 feet) is near Marinette (sections K'–K' and E'–E'). The formation thins to the south and east where it has been completely removed by erosion. The upper part of the Jordan Sandstone is the Coon Valley Member, which is a sandy dolomite and constitutes most of the thickness of the Jordan Sandstone in this province (Odom and Ostrom, 1978).

The entire surface of the dolomite of the Prairie du Chien Group has been eroded, and the formation has been entirely eroded away in the south-central part of the province (section B'–B' and parts of sections D'–D' and F–F'). In much of this area, the Jordan Sandstone, the St. Lawrence Formation, the Tunnel City Group, and the Wonewoc and the Eau Claire Sandstones also have been removed by erosion. The rocks of the Ancell Group were deposited on the eroded surface.

Most of the thickness of the Ancell Group consists of rocks of the St. Peter Formation. The St. Peter Formation is a medium- to coarse-grained sandstone that is poorly cemented by dolomite in most places and by limonite locally (M.E. Ostrom, Wisconsin Geological and Natural History Survey, written commun., 1982). The upper part of the Ancell Group, the Glenwood Formation, is a thin (0–60 feet) sandy dolomite that overlies the St. Peter Formation in some areas of the province (Mai and Dott, 1985). The Ancell Group is as much as 300 feet thick in the south-central part of the province where pre-Ancell Group erosion was greatest.

The rocks of the Sinnipee Group are gray to brown dolomite and limestone with some green shale (M.E. Ostrom, Wisconsin Geological and Natural History Survey, written commun., 1982). The thickness of the Sinnipee Group is fairly constant (200–260 feet) where it is not eroded. The Sinnipee Group yields water to domestic wells where it is the upper bedrock; its permeability is due primarily to secondary fracturing and solution cavities in its eroded upper surface. Rocks of the Sinnipee Group are of low permeability and are a confining unit below the upper weathered zone and in areas where they are overlain by Maquoketa Formation.

The rocks of the Maquoketa Formation are blue-green to green-gray shale, dolomitic shale, and dark-brown to brown-gray dolomite. The thickness of the Maquoketa Formation is fairly constant (170–200 feet) from Racine to north of Manitowoc (section F–F'), where it thickens abruptly to about 400 feet. The Maquoketa Formation is a confining unit between the Silurian dolomite aquifer and the underlying sandstone aquifer, although it is tapped for domestic ground-water supplies locally in the north.

The hematitic shale of the Neda Formation was deposited in depressions in the Maquoketa Formation and later eroded (Alfredo Rosenzweig, University of Wisconsin, unpub. M.S. thesis, 1951). The Neda Formation is scattered in the south and along the eastern shore of Green Bay. The maximum known thickness of the Neda Formation is about 55 feet at Manitowoc (sections F–F' and F–F'). The Neda Formation is part of the Maquoketa confining unit.

Dolomite of the Silurian System is the uppermost bedrock in most of the eastern part of this province. The thickness of the Silurian dolomite ranges from less than 100 feet along its western edge to greater than 600 feet along Lake Michigan from Ozaukee County north. The Silurian rocks generally yield sufficient quantities of water for domestic and small industrial supplies, but yields differ areally. The permeability of the Silurian dolomite is due primarily to secondary fracturing and solution channels. Silurian rocks are covered by glacial deposits except for scattered local exposures, exposures along an escarpment on its western edge, and a small area covered by Devonian rocks along Lake Michigan.

Limestone and shale of the Devonian System are present along the Lake Michigan shoreline between Milwaukee and Sheboygan (section F–F') (Mudrey and others, 1982). The Devonian rocks are more than 200 feet thick north of Milwaukee. Few wells are completed in Devonian rocks.

UNCONSOLIDATED DEPOSITS

Unconsolidated deposits in this province consist of Pleistocene glacial deposits. Glacial deposits generally are less than 200 feet thick within most of the province, but thicknesses are greater in buried preglacial river valleys (Trotta and Cotter, 1973). Glacial deposits are greater than 400 feet in the Troy bedrock valley that extends southwest from south-central Waukesha County through Walworth County and into Illinois (Green, 1968; Trotta and Cotter, 1973); the Troy valley intersects section C'–C' near Elkhorn. Young and Batten (1980) reported glacial deposits greater than 500 feet thick in a preglacial valley system that extends southwestward from west-central Washington County into Waukesha County. The thickness of glacial deposits in the preglacial Wolf River Valley in Oconto and Outagamie Counties is greater than 300 feet (Trotta and Cotter, 1973).

In preglacial valleys, glacial deposits generally yield sufficient quantities of water for public water supplies. In other areas, these deposits generally are used only for domestic water supplies.

VERTICAL GROUND-WATER FLOW

Flow simulations by Mandle and Kontis (1992) indicate vertical recharge to deep aquifers in the west where hydraulic heads decrease with depth and an increase in hydraulic heads with depth in the east except where heavy pumping has caused a reversal of head gradients. Before development, head gradients increased with depth throughout the Maquoketa confining unit along Lake Michigan (section F–F'), but heavy pumping from deep aquifers in southeastern Wisconsin has reversed these gradients, as shown at the southern end of section F–F'. Hydraulic heads also generally increase with depth across the St. Lawrence–Tunnel City and the Eau Claire confining units in the eastern part of the province.

Probably very little ground-water flows through the Maquoketa confining unit because of its low vertical permeability. Most ground-water flow beneath the Maquoketa confining unit probably is to the east and south in the direction of the dip of the Paleozoic rocks.

DISSOLVED-SOLIDS CONCENTRATION IN GROUND WATER

Previous summaries of dissolved-solids concentrations in ground water in this province indicate that concentrations in water from shallow aquifers (glacial deposits and uppermost bedrock) generally are in the range of 300 to 500 milligrams per liter (Kammerer, 1984, P. 22–23; 1995). Dissolved-solids concentrations in water in deep aquifers generally increase with depth and in the direction of regional ground-water flow.

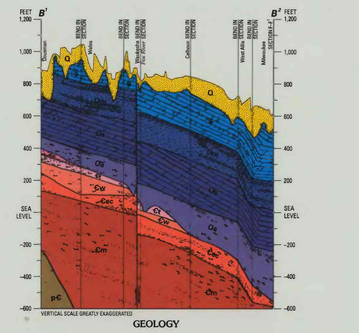
Zones of saline water have been identified in bedrock aquifers in eastern Wisconsin. Ryling (1961) delineated zones of saline water in the Silurian dolomite and upper sandstone aquifers in northern Milwaukee and southern Ozaukee Counties, the sandstone aquifer in eastern Sheboygan County (section D'–D' and F–F'), and the Silurian dolomite aquifer in northeastern Manitowoc County (section F–F'). He also reported saline water in the sandstone aquifer at Marinette (section E'–E') and east and northeast of Lake Winnebago.

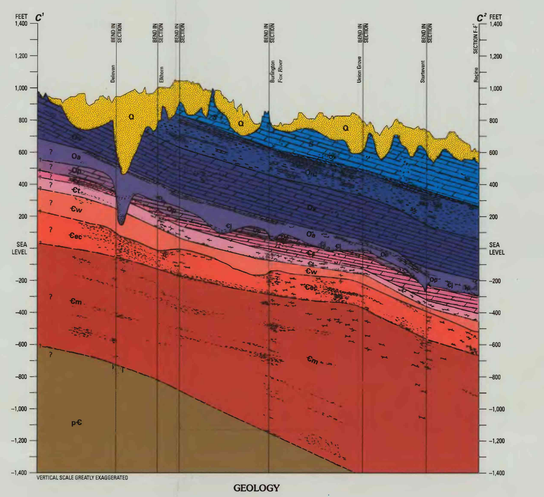
Placement of lines of equal dissolved-solids concentration through deep aquifers in eastern Wisconsin is conjectural because of the lack of hydrologic and water-quality data. Aquifers suspected of yielding saline water commonly are avoided in favor of alternative aquifers or surface-water supplies. Wells that do penetrate deep aquifers and zones of saline water generally draw water from multiple aquifers.

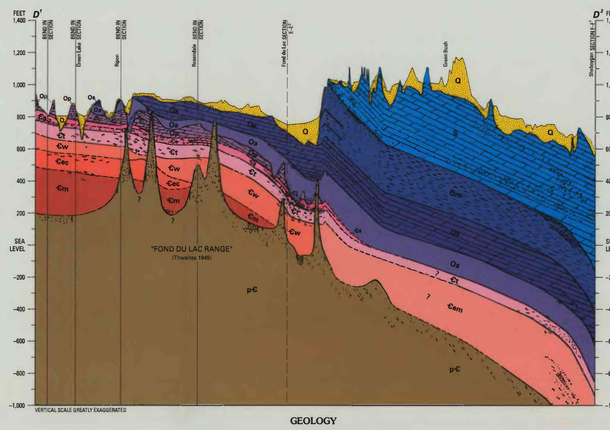
CONVERSION FACTORS

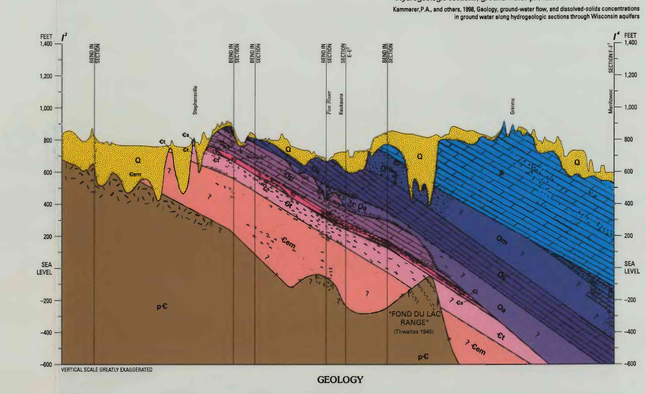
To obtain measurements in meters, multiply feet by 0.3048.

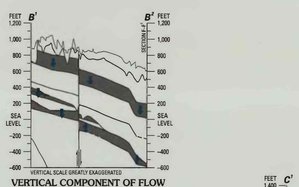
Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NVGD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.



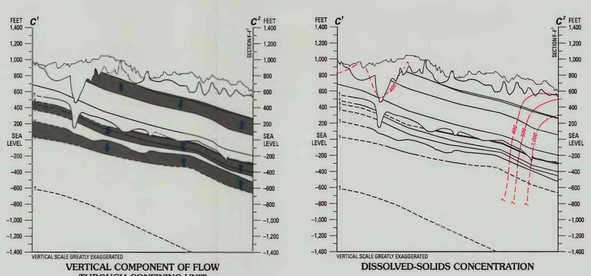








VERTICAL COMPONENT OF FLOW THROUGH CONFINING UNIT



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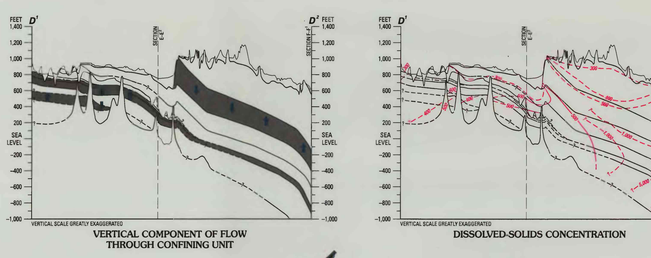

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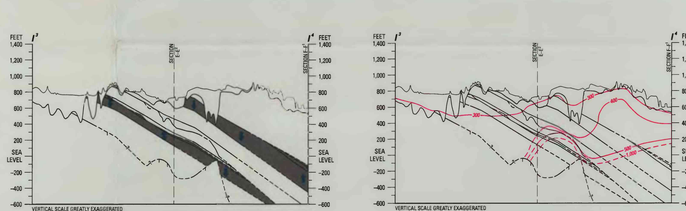

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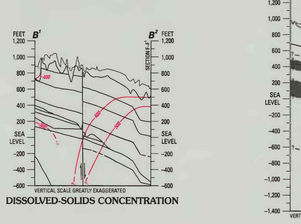

DISSOLVED-SOLIDS CONCENTRATION

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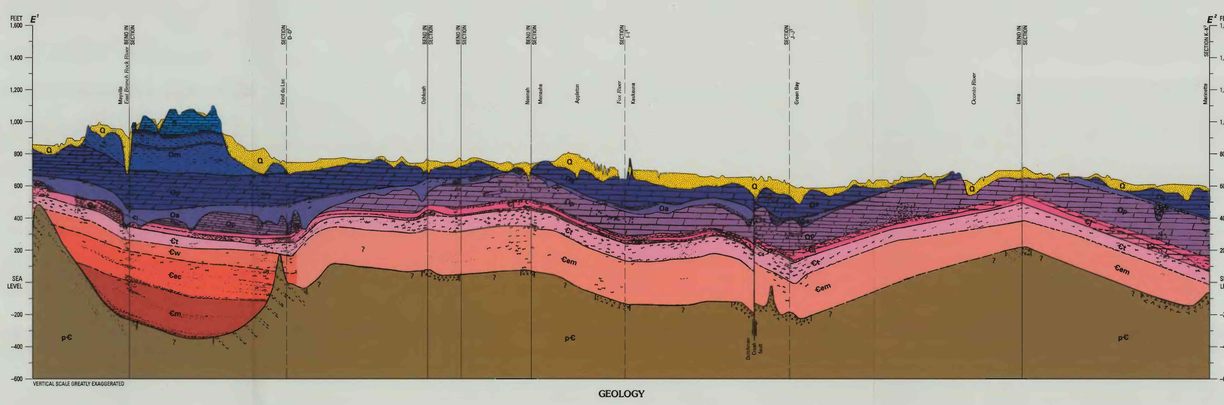

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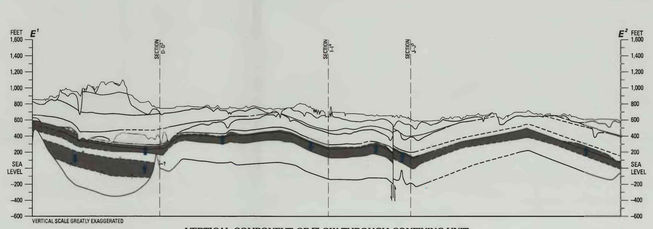

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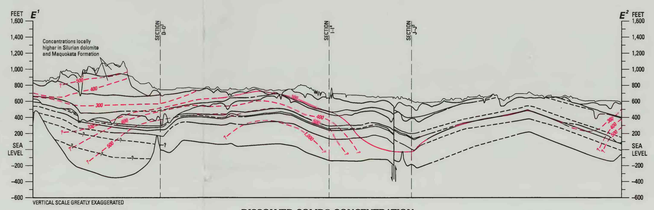

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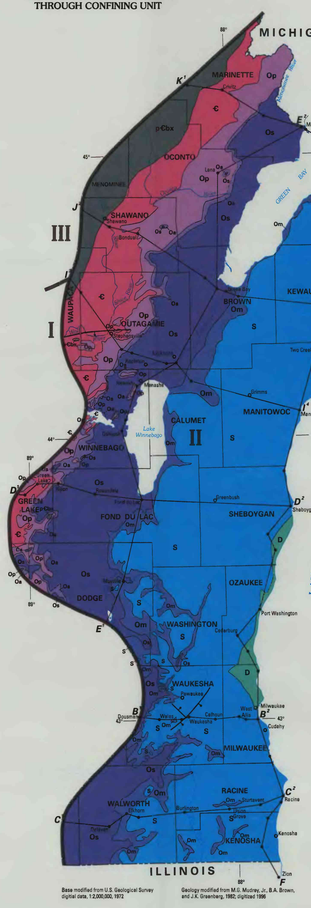

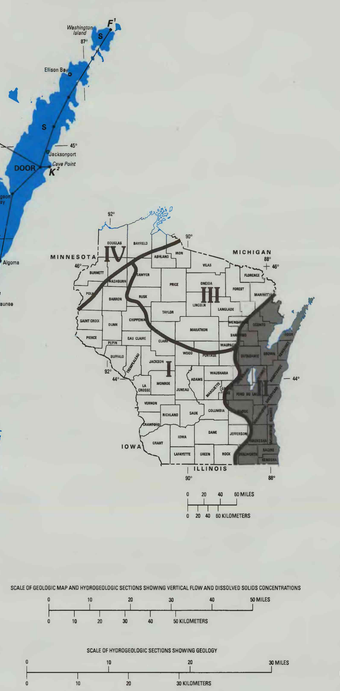

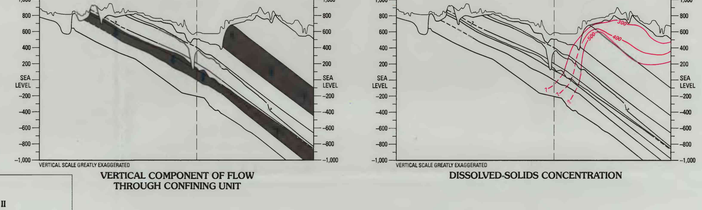

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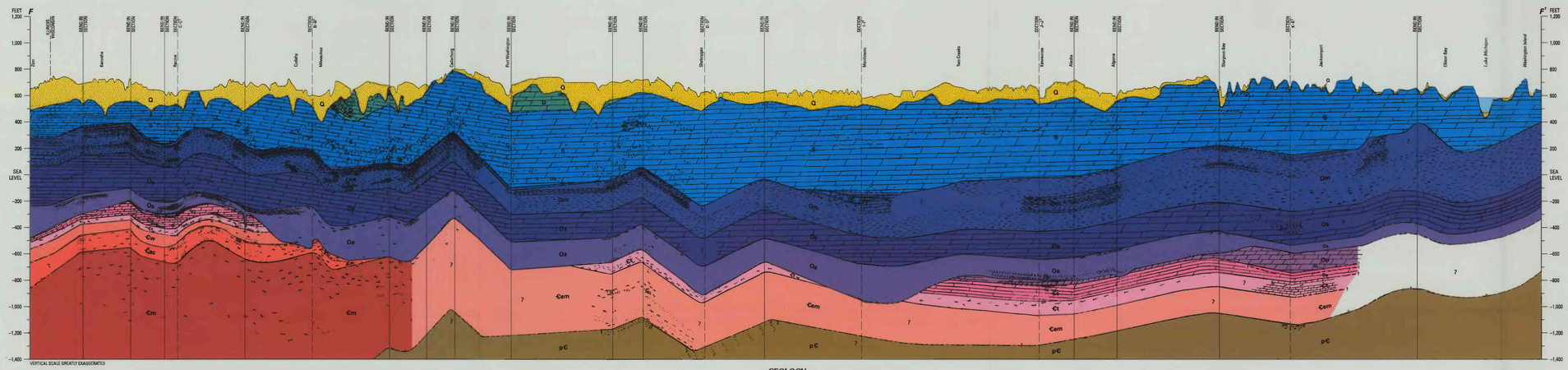
DISSOLVED-SOLIDS CONCENTRATION



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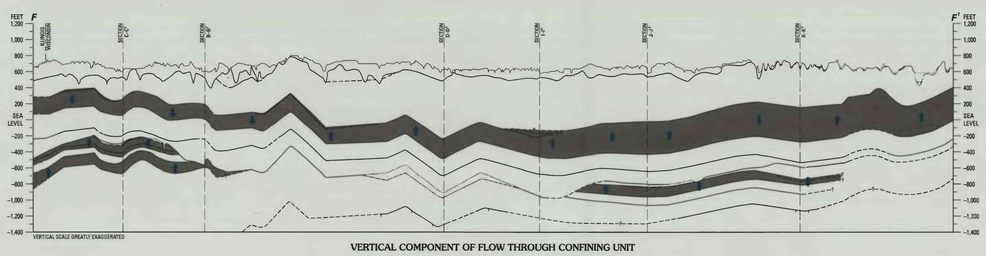

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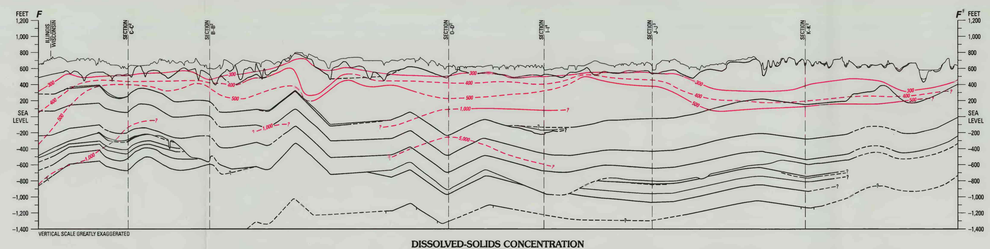

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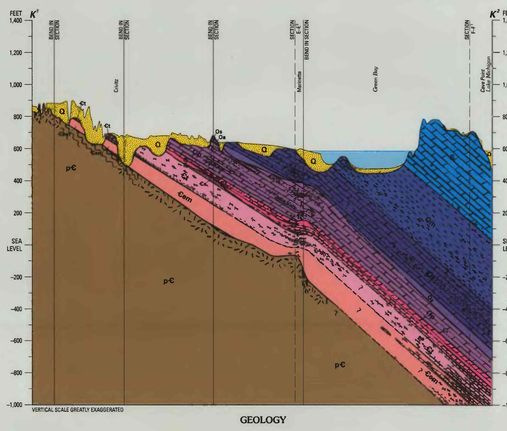

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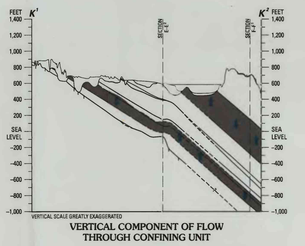

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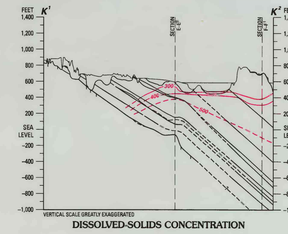

DISSOLVED-SOLIDS CONCENTRATION

EXPLANATION

Unit on map	Unit in section	Geologic units in ground-water province II
QUATERNARY	Q	Holocene alluvial and Pleistocene glacial deposits
DEVONIAN	D	Devonian system, undivided
SILURIAN	S	Silurian system, undivided
	On	Neda Formation
	Om	Maquoketa Formation
	Os	Sinnipee Group
ORDOVICIAN	Oa	Ancell Group
	Op	Prairie du Chien Group
	C	Cambrian system, undivided
	Cj	Jordan Sandstone
	Cs	St. Lawrence Formation
	Ct	Tunnel City Group
	Cem	Elk Mound Group
CAMBRIAN	Cw	Wonewoc Sandstone
	Cec	Eau Claire Sandstone
	Cm	Mt. Simon Sandstone
	pC	Precambrian rocks, undivided
PRECAMBRIAN		Basement complex

Lithology

CENOZOIC — Unconsolidated materials composed of clay, silt, sand, gravel, and boulders. Specific lithology not shown

Major rock type	Secondary lithology
Dolomite	Dolomitic
Shale	Shaly
Siltstone	Silty
Sandstone	Cherty

PALEOZOIC AND PRECAMBRIAN — Conglomerate

PRECAMBRIAN — Granitic rocks massive to foliated including quartz, monzonite, and syenite; Quartzite, rhyolite, and conglomerate; Metavolcanic rocks including diorite and gabbro; Schist and gneiss including metasedimentary rocks; Volcanic rocks; ? Lithology unknown

- **Contact**—Dashed where approximately located. Queried where inferred
- **Fault**—On map, ball and bar on downthrown side. On section, arrows indicate direction of vertical movement
- **Ground-water province boundary and province number**
- **Surface trace of hydrogeologic section**—Letters identify end points and intersections with ground-water province boundaries. Solid circles show locations of turning point wells and municipality where turning point is located
- **Vertical component of flow through confining unit**—Arrow indicates vertical direction of ground-water flow through confining unit (modified from Mandle and Kontis, 1992)
- **Line of equal dissolved-solids concentration**—Dashed where approximately located. Queried where inferred. Interval, in milligrams per liter, is variable
- **Municapility located near hydrogeologic section**

Hydrogeologic sections, ground-water province II

GEOLOGY, GROUND-WATER FLOW, AND DISSOLVED-SOLIDS CONCENTRATIONS IN GROUND WATER ALONG HYDROGEOLOGIC SECTIONS THROUGH WISCONSIN AQUIFERS

By
Phil A. Kammerer, Jr., Lee C. Trotta, David P. Krabbenhoft, and R.A. Lidwin

1998

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